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(Research Article)

Future of Gasoline Stations

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Abstract

The gasoline fueling stations' future during the automobile industry shift towards electric is questionable. With more than 196,000 gasoline fueling stations in the United States, many of them require an upgrade to electric charging stations. The regular fueling time from gasoline stations is significantly less than the charging time from an electric charging station. Preparedness for shifting from gasoline stations to electric vehicle (EV) charging stations requires detailed research on how consumer behavior changes given they will have a readily available charging port in their households. It would be essential to categorize the customers based on their preferences and thus plan the approach for meeting their needs. For large gasoline stations, the shift to EV charging stations becomes a viable choice as they tend to attract trucks and other travelers throughout the year. A model of electrical infrastructure was prepared for a large gasoline station by using the estimated number of customers visited. Improvement of amenities or devising a way to attract customers will be required to allow them to spend the waiting duration comfortably.

Keywords: Electric Charging Infrastructure; Gasoline Fueling Station; Direct Current Fast Chargers; Electrical Service

1. Introduction

The market for automobiles is shifting towards electric vehicles and sooner widespread electrification is supposed to happen [1]. Electric vehicles are a growing choice when the utilization of clean and green energy is concerned with conserving nature. The government targets the new electric vehicle sales to be at 50% by 2030 [2]. So, the Energy Protection Agency outlined that 56% of the entire car and light-duty truck sales will be electric vehicles. Georgia was reported to have more than 24,000 electric vehicles in 2021, and in 2023, they were reported to be around 75,000 [3]. Thus, indicating strong signs of a rapid increase in electric vehicles in the past few years. Where fossil fuel depletion is concerned, an energy crisis is evident. Thus, preparedness for the transition to renewable energy for generation and switching to electric vehicles becomes a viable solution. EV charging infrastructure becomes important when the majority of on-road vehicles are anticipated to transform to electric. Based on current market trends, electric vehicle penetration is going to reach about 100% at some point in the upcoming decades. This is alarming for gasoline stations when some studies indicate unprofitability from gasoline stations due to electrification [4]. A typical layout of a medium-sized gasoline station with store and fueling points is shown in Fig. 1. When a conversion to an electric charging station is considered, Fig. 2. shows the tentative location of new charging stations. Home EV charging is a proposed solution for customers to meet their increased demand for EV [5]. However, with improved EV motor design, large-scale transition becomes smoother [6].

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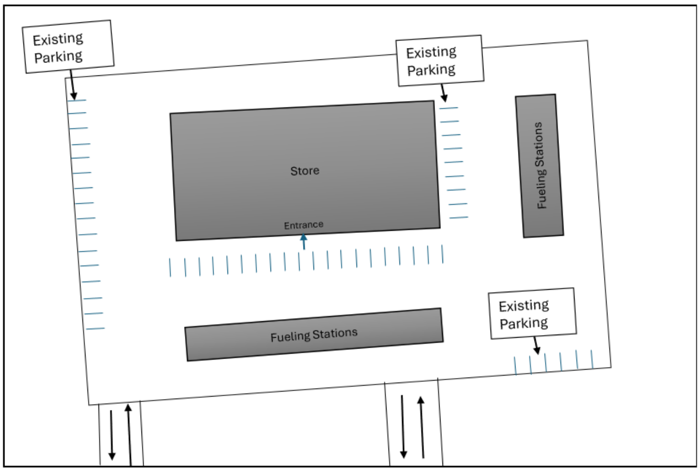

Figure 1 Existing Layout of Gasoline Station

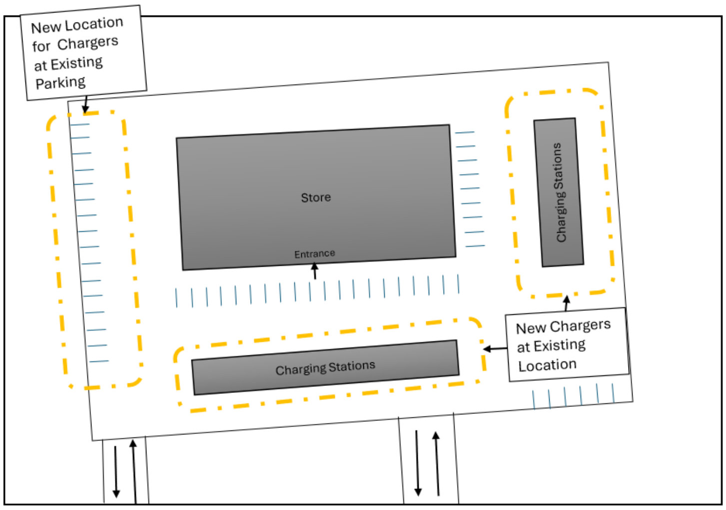

Figure 2 Locations for Chargers

1.1. Customer Preferences

Customers seek trade-offs between the time taken to charge, time taken to travel to the station, and distance from the station [7]. Customers have the availability of charging while parked at home. Some customers living in apartment communities with no readily available parking space near their building face challenges with overnight parking. Most homeowners will utilize home charging as they return home and leave the car to charge overnight and ready for use the next day. Thus, the overall need for commercial EV charging stations is reduced. Small gasoline stations conversion to EV charging stations must consider that there will be a reduced demand for EV charging stations because of the availability of home charging infrastructure. Additionally, many without readily available charging infrastructure at their apartment homes may seek dedicated parking spaces within the apartment community that allow charging while parked overnight. This further reduces the demand for the charging stations. However, for long-route drivers such as trucks and other travelers, fast charging stations become a preferable option. Thus, many gasoline stations, when converting to EV charging stations, will continue to see a rising demand. Thereby conversion to EV charging stations is a feasible option. Conversion of existing retail spaces to accommodate with range of products and services, modernization, and improve waiting user experience while they wait, requires a thought from existing gasoline station owners [8].

1.2. Decision Making

Decision-making for the choice of charging infrastructure for a user depends heavily on individual needs and preferences based on the situation they are exposed to. Fig. 3. shows blocks that show available charging infrastructures and decision-making criteria for any situation. For example, a long-trip traveler staying in a hotel might prefer to park

at the hotel designated parking for EV charging overnight, whereas a short-trip traveler returning home might prefer to charge the battery at home. Additionally, how sooner the user returns for charging also determines type and frequency of the charging at a given preferred location. The overall decision is also predominated by cost incurred for the charging [7]. For example, charging at home during the night gets to take benefit from reduced time of the day tariffs. Some higher charges at commercial fast charging discourage the users. (1) shows how a selection of charging (S) depends on several factors such as trip length, charging time, cost, and convenience. Based on the selection the choices are home charging, charging at nearest parking, at existing gasoline stations, or other locations.

$$S = f(trip\ length, charging\ time, cost, convenience) \qquad (1)$$

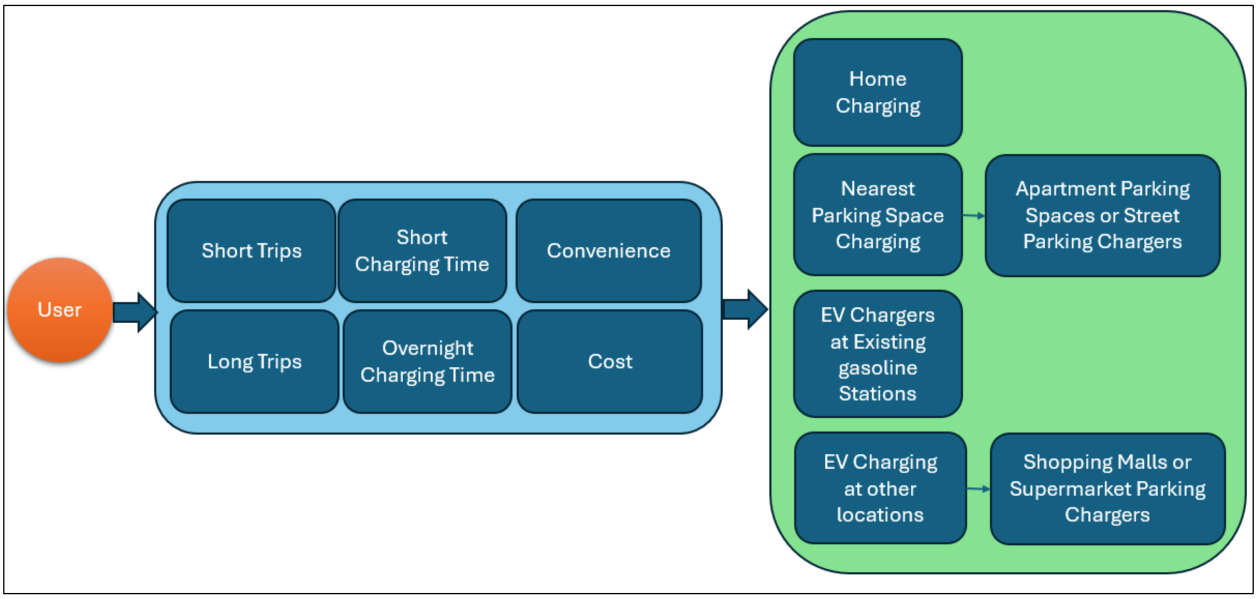

Figure 3 User's Selection

2. Methods

Considering an average customer returns to a charging station located at the existing gasoline station, all gasoline stations conversion to EV charging stations is possible. The available charging infrastructure includes level 1, 2, and 3 chargers. The electrical capacity in KW and charging times vary depending on the type of charger. Long charging times associated with levels 1 and 2 make them less suitable where reduced charging times are concerned. A DC fast charger is capable of charging between 20 minutes to 1 hour and most powerful choice in terms of charging capabilities [9] [10]. The authors also presented cost and time being important factors for users to selection of charging needs [10]. Based on historical traffic at a given gasoline station with an average number of vehicles visited on an hourly basis, the analysis was performed to accommodate as many charging infrastructures as possible to support given vehicles visiting an hour.

To allow fast charging it was assumed that a single port DCFC suits the need to ensure improved charging times for the customer. The simple formula for obtaining the ampacity of the electrical service is given by (2). Where, I is the current in (Amps), N is the number of chargers, W is the wattage of the charger, and V is the rated voltage of electrical service. I is rounded to the next available electrical service size available from utility company [11].

$$I = \frac{(1.25)NW}{\sqrt{3}V} \qquad (2)$$

Let us consider a large gasoline station with more than 300 visitors on an hourly basis. Available 315 parking spaces can easily accommodate a single port DC fast charger. With a given case, a total quantity of three hundred fifteen (315) DCFC at 50kW is proposed. This equates to a medium voltage electrical service of minimum 1200 A at 13.8kV, 3Phase. The demand factor is considered at 100%, keeping in mind users should not face decreased time in charging due to the factored demand factor, which reduces the electrical service size in terms of its rated ampacity. Any open grassy area at the corner of the property line is suggested as the tentative location for the New Electrical Room. A total of seven (7) 13.8kV to 480V transformers will step down the utility medium voltage of 13.8kV to the required 480V to power the

DCFCs at rated voltage. Seven (7) switchboards and/ or electrical panelboards supporting forty-five (45) chargers fed from each of the switchboards will be located inside the new electrical room.

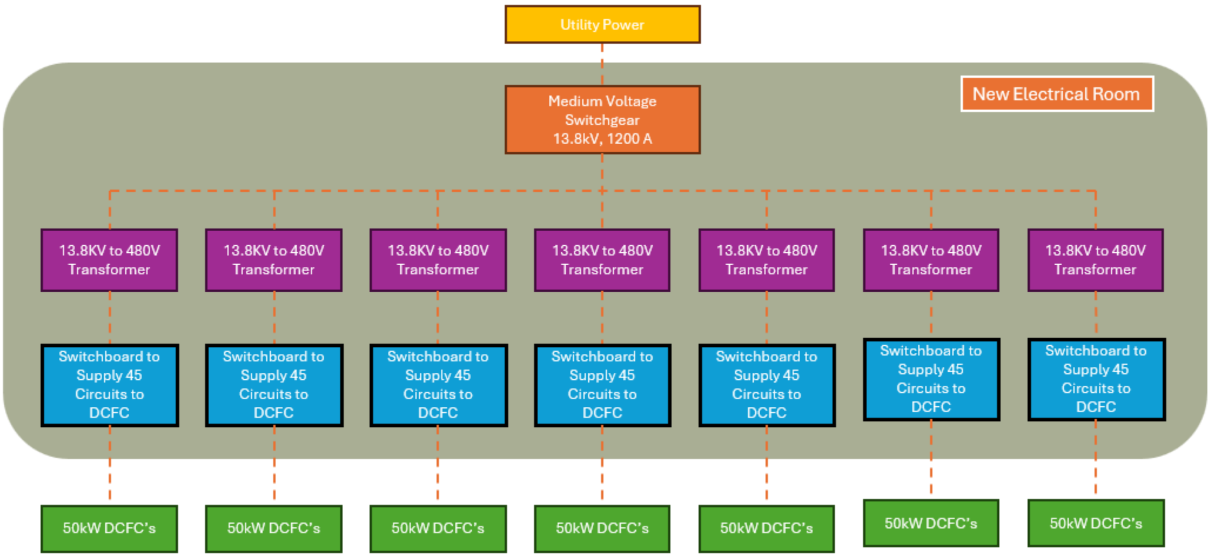

Figure 4 Electrical Layout

2.1. Challenges

There are several challenges to the installation of a large quantity of electric vehicle chargers. Some of them are enumerated in the following section. Mainly, site redevelopment, maintenance of effective movement of traffic, supply chain issues in availing charging infrastructure equipment, grid power availability, and funding pose challenges for this large-scale transition. Other factors include consumer behavior with evolving technology in products related to EVs and their charging equipment.

Reduction of useful driveway: Many parking spaces have limited area available to add DCFC and thus to accommodate the increased footprint of DCFC on existing parking spaces, the driveway areas will shorten in width. This becomes a concern only for parking spaces other than ones located along the periphery of the site. However, selection of DCFC's with compact and sleek size promises a reduced footprint and ease in installation without impacting the driveways around the store.

Availability of charging stations: Since there are long lead times for chargers, how long the large orders for commercial DCFC's arrival take is questionable. Many premium products also pose challenges with premium charges paid for purchases. Additionally, evolving technology in charging stations with improved charging capabilities results in users planning the purchase of the best available product at a given time.

Site Redevelopment: While existing gasoline fueling is under operation, how the construction of electric charging infrastructure is phased out becomes a challenge. A streamlined phasing plan by evaluating the traffic movement by time of the day, day of the month, or month of the year is advisable. Many small pilot products to learn how the system performs require utilization of existing infrastructure, such as reusing spare capacity of the parking lots and electrical service for the addition of charging infrastructure. This minimizes the need for additional site space.

Availability of power: The preparedness of utility companies to provide medium voltage power supply to commercial gasoline fueling stations appears to be less traditional. Thus, whether utility companies are prepared to provide the increased load from large-scale DCFCs is questionable. Some utility companies may experience increased load from such additional requests and thus may have deficit resources to cope up.

Availability of funds: Allocation of funds for this development becomes a challenge when future planning is concerned by internal business teams. Businesses rely on return on investment, and some businesses require capital investment support from third-party agencies. Thus, planning the fund allocation and availing it when needed is questionable. The role of funds from government agencies to expedite the transition plays a crucial role [12].

Although there are challenges to the large-scale development of electric chargers at any existing commercial gasoline station, phasing the work is a viable solution. For example, a pilot deployment of a given quantity of chargers in next few years and thus growing chargers based on market trends of electric vehicles. For smaller gasoline stations, the change is easier but whether it's a feasible choice to go ahead depends on their monthly sales figures and how users' behavior changes with electrification. Users prefer to see EV stations with simple amenities, proper signages, access to the internet, and so on [13]. Improvement of reliable charging [14] along with the development of modernized outfits [15] for the stores becomes a challenge when funding is concerned for such redevelopment. Lesser availability of EV charging infrastructure significantly limits the EV potential [16]. Some gasoline stations offer excellent amenities, and drivers tend to spend extended time even with their gasoline-fueled vehicles [17]. Increased wait times for recharging at stations call upon some amenities that keep the customers engaged, such as shopping, watching television, playing certain games, and so on.

3. Conclusion

Fig. 4 presented the size of the electrical service, and the quantity of DC fast chargers required. To cope with rising electric vehicles and their 100% transition in upcoming years, it is recommended to upgrade with electric vehicle charging stations at all available parking spaces and existing gasoline fueling points. A total of three hundred fifteen (315) DC fast chargers at existing customer parking spaces were recommended for a large gasoline station. To support the charging infrastructure, a 1200A, 13.8kV, 3-Phase medium voltage power is required, and a proposed location of an outdoor electrical room with electrical equipment required was presented. The challenges related to infrastructure development were mainly the supply chain issues of charging infrastructure (mainly DCFC's) availability in the market, utility power availability, and strategies for coping with rising electric vehicles in the market. Phasing of the work was suggested as the recommended solution.

3.1. Future Aspects

The charging time reduction with charging infrastructure rated at higher power (or wattages) when chosen to address increased charging times, opens a window for discussions on increased power required from utility companies. As technology continues to evolve, types of charging infrastructure and, hence, its power requirement vary and become a topic of research both at development and deployment. When the technology is evolving both for charging infrastructure and EV, businesses planning their future course of action are heavily dependent on consumer behavior for the rising transition. Home energy management systems (HEMS) integrate the newly added charging demand for residential housing units [5]. However, the exact behavior of customers when there are options available for charging at both residences and other commercial properties becomes a threat to the traditional gasoline station transition. Many selling points for current gasoline stations include the store amenities. Understanding consumer behavior during this shift to EV is the underlying aspect and requires further assessment.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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